Sizing Electric Power Systems

For Model Aircraft

Flightline Hobby Seminar
Nov 1, 2014

Four Ps of Electric Power

- Power
- Pack
- Pitch Speed
- Prop

1) Power

- Power to weight ratio critical to performance
- **For typical sport flying > 100 watts/lbs**
  - Prop/battery may be less than motor capacity
  - Three bladed prop will be less efficient
  - Consider motors rated 100 to 150 watts/lbs
- For 3D flying ~ 200 watts/lbs
- Scale flying possible with ~ 80 watts/lbs

1) Ultra Micro

- ESC max current = 2.0 amps, ~ 8 watts (est)

- 1S UMX models
  - T28   1.4 oz   8 / (0.087) = 92 watts / lbs
  - P51   1.5 oz   8 / (0.094) = 85 watts / lbs
  - F4U   1.6 oz   8 / (0.100) = 80 watts / lbs

1) Gliders: Parkzone Radian

- ESC max current = 30 amps, ~ 300 watts (est)
  - [†]25 amps * 12v ~ 300 watts

- 30 oz = 1.9 lbs
- 300 / 1.9 = 160 watts / lbs

[†]*Assumes ESC is not maxed out*

1) Gliders: Eflite Mystique

- 4.4 lbs
- Power 25, 600 watts recommended
- 600 / 4.4 = 136 watts / lbs

1) Motor Kv

- Kv (no load rpms per volt)
- Kv * Volts = no load RPM
  - Higher Kv (in general)
    - Smaller props and/or lower voltage packs
  - Lower Kv (in general)
    - Larger props and/or higher voltage packs

- Voltage * Kv ~ 12,000 RPM similar to glow
- RPM in flight ~ 10,000 RPM (80% of no load)

1) Typical Motor Kv

			No Load RPM
• 2S (240)	Sport	- 2,500 Kv	20,000
• 3S (2100)	Prop Jet	- 2,200 Kv	25,200
• 3S (2100)	Sport	- 960 Kv	11,500
• 3S (3200)	Scale	- 740 Kv	8,900
• 4S (3200)	Sport	- 740 Kv	11,840
• 4S (3200)	3D	- 1,000 Kv	16,000
• 6S (3200)	3D	- 525 Kv	12,600

1) Typical Motor Kv

Sport planes typically around 12,000 RPM (no load)
Kv * pack voltage ~ 12,000
RPMs in level flight approximately 10,000 RPM

				No Load RPM
				,000
				,200
• 3S (2100)	Sport	-	960 Kv	11,500
• 3S (3200)	Scale	-	740 Kv	8,900
• 4S (3200)	Sport	-	740 Kv	11,840
• 4S (3200)	3D	-	1,000 Kv	16,000
• 6S (3200)	Sport	-	525 Kv	12,600

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• 3			0
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Fast prop jets or 3D planes may have a no load RPM higher than 12,000 RPM

1) Typical Motor Kv

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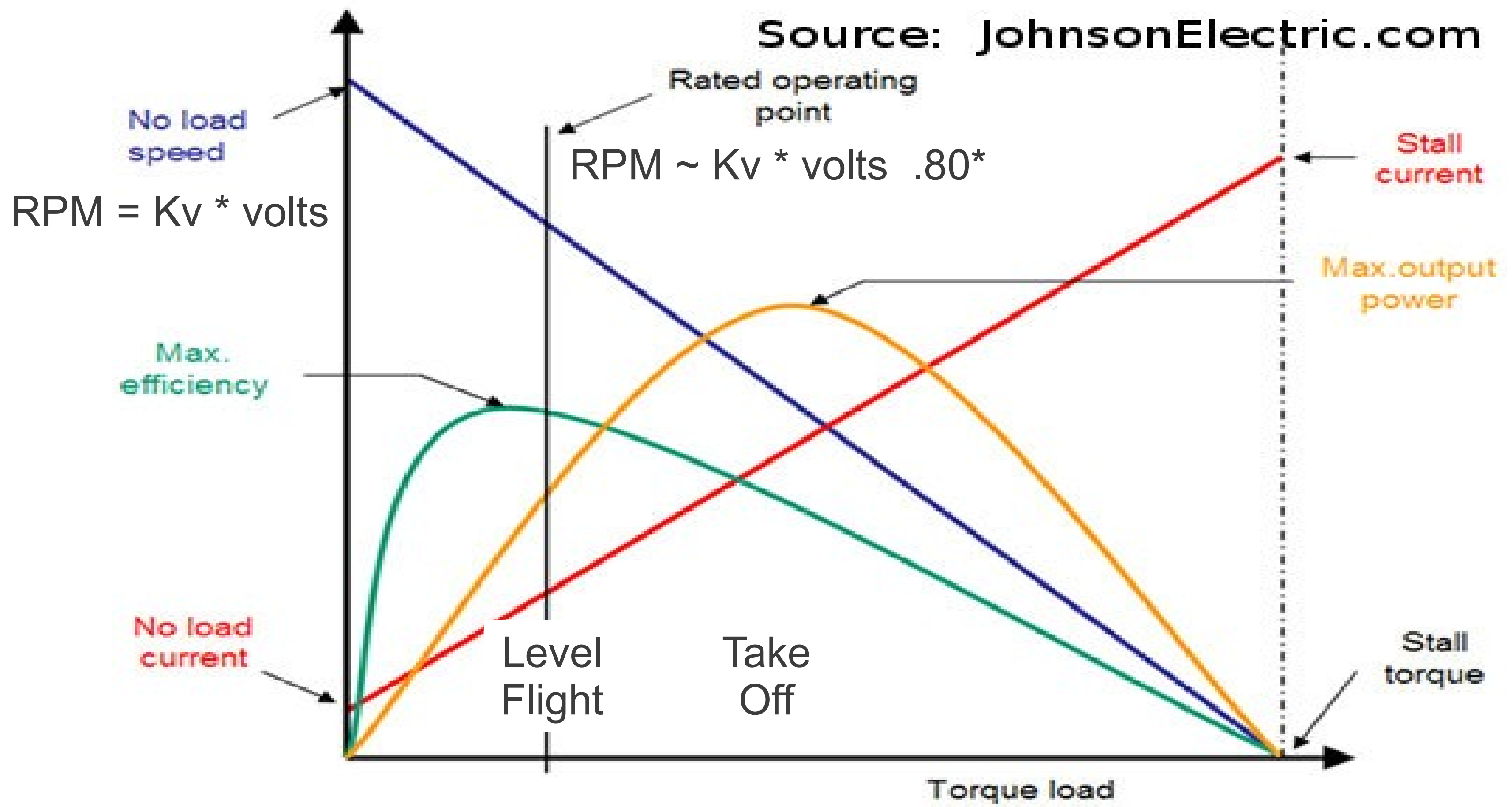
Many motors provide a choice of no load RPMs.
Fewer cells (lower voltage) = lower RPMs, bigger prop.
More cells (higher voltage) = higher RPMs, smaller prop.

The higher voltage set up will draw less current to generate the same power. Typically, this will make higher voltage systems more efficient.

1) Brushless Motors

- Voltage is speed
- Current is torque
- Often more than 80% efficient
  - When operating at the designed load
  - Voltage and prop determine load

1) Brushless Motors



Assumes the prop is recommended for that motor and voltage

1) Example

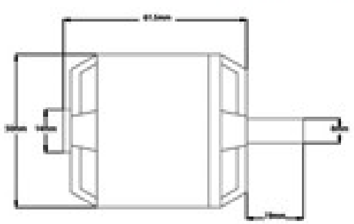
- To electrify a Four Star 40:
  - Weight ~ 5 lbs
  - Power range 500 to 750 watts continuous:
    - Eflite Power 32 (700 watts, 770 kV) 3 to 5 S
    - Rimfire .32 (850 watts, 800 kV) 4 S Recommended
      - Rimfire 25 was only 650 watts max continuous
      - With 4S pack and prop, power likely to be less than 750 watts

1) Example

- Manufacturer recommendations

RimFire .32

- *Includes prop adapter and motor mount.*



Source: Electrifly.com

GPMG4700

Description	Stock No.	Diameter	Length	kV	Constant Watts	Burst Watts	Weight	Shaft Diameter (mm)	Voltage Range	Sport	3D	Power System Recommendation		
												ESC	LiPo	Prop
RimFire .32	GPMG4700	42 mm (1.7 in)	50 mm (2.0 in)	800	850	1480	198 g (7 oz)	5 mm (0.2 in)	11.1-14.8V / 3-4S LiPo	2950 g (6.5 lbs)	1845 g (4 lbs)	45 Amp	4S	12x6 to 13x8 Electric

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- For gliders ~ 150 watts/lbs
- For 3D flying ~ 200 watts/lbs
- Scale flying possible with ~ 80 watts/lbs

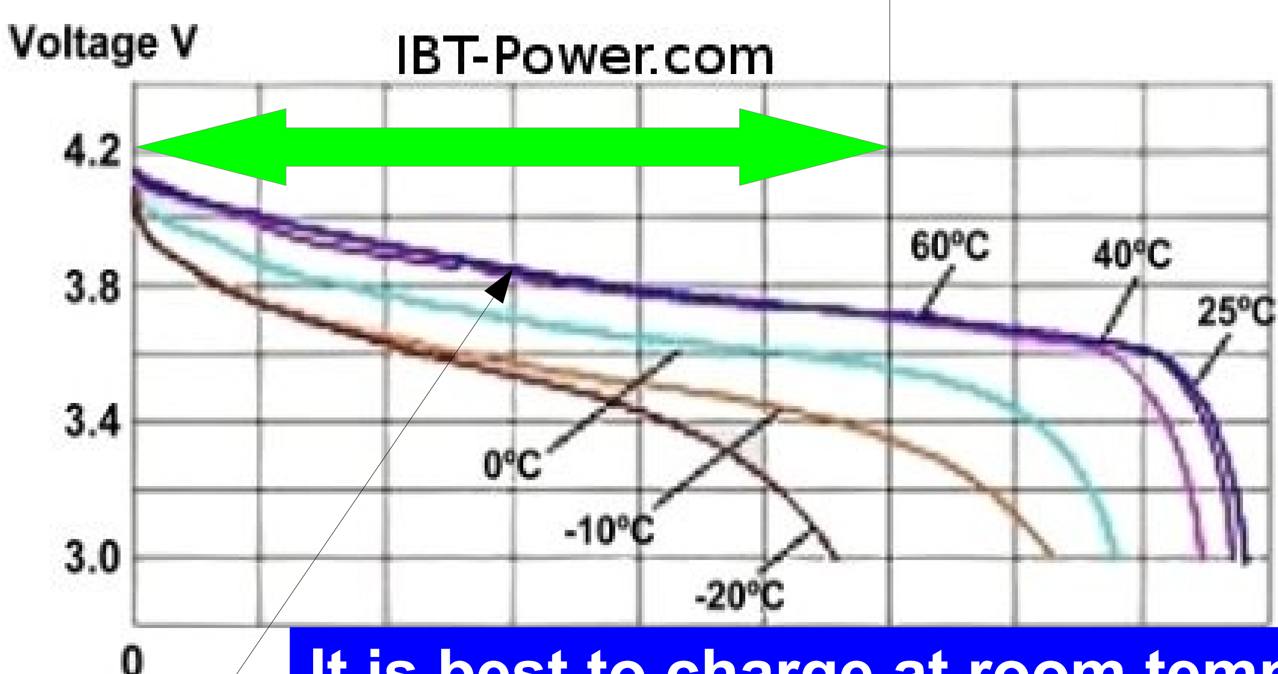
2) Pack

- Voltage (Volts)
- Capacity mAh
  - 1 amp*hour = 1 amp for 1 hour
  - 1,000 mAh = 1 amp*hour

LiPo battery packs assumed

2) Pack Voltage

- LiPo cell voltage range 3.75 to 4.20 volts
  - Longer life if voltage kept in this range
  - Voltage measured open circuit (no load)



3.82 V ~½ flight

It is best to charge at room temperature. When cold, voltage drops.

2) Pack Voltage

- For initial estimations, a nominal 4 volts per cell can be used.
- 1S ~ 4 volts
- 2S ~ 8 volts
- 3S ~ 12 volts
- 4S ~ 16 volts

2) Pack Current

- Watts = V*I
- I = Watts/V
  - For a 750 watts motor:
  - For 3S: 750 / 12 = 62 amps
  - For 4S: 750 / 16 = 47 amps
- Loss = $I^2 * R$
- ***Higher voltage systems more efficient***

2) Pack Capacity

- Initial Estimate:
- Ah = max current / 15 (high performance)
- Ah = max current / 12 (longer flight time)

- 4S (3200) 750 Watt Example:
  - Max current 47 amps
  - Ah = 47 / 15 = 3.2 amp/hrs
  - mAh = Ah * 1000 = 3200 mAh

2) Pack Capacity UMX

- Initial Estimate:
- Ah = max current / 15 (high performance)
- Ah = max current / 12 (longer flight time)

- Example:
  - Max current = 2 amps
  - 2 / 15 = 0.133 = 133 mAh
  - 2 / 12 = 0.167 = 167 mAh

Stock Battery
150 mAh

2) Pack Capacity Gliders

- Mystique Example ~ four climbs:
  - Max current = 44 amps
  - 44 / 15 = 2.9 = 2900 mAh
  - 44 / 12 = 3.7 = 3700 mAh

Stock Battery
3200 mAh
30C

- Single Climb:
  - **44 / 30** = 1.5 = 1500 mAh (1300 mAh standard)
  - Max current = 44 amps * 30 seconds = 367 mAh
  - 30C * 1.3 = 39 amps
  - 45C * 1.3 = 58 amps
  - ***In theory***, a 1300 mAh 45C battery should climb once

Consider batteries rated over 30C when total powered flight time is ~4 min or less.

2) My Favorite Packs

- 2 to 2.5 lbs sport planes
  - 3S 2100 packs, ~ 350 watts
  - Economical batteries, many park fliers
    - Parkzone Corsair, T28, SE5a, Multiplex Fun Cub, Flyzone Tidewater, many others

2) My Favorite Packs

- 4 to 5 lbs sport planes
  - 4S 3200 packs, ~ 750 watts
  - Enables a flatter prop than 3S systems
    - Reduced yaw and roll on take off
    - More critical for 3D
  - Efficiency of higher voltage than 3S
    - Carbon Z yak
    - Optional for others specifying 3S 3300 mah pack
      - Eflite Rhapsody, .15 Ultimate Bipe

2) Pitch Speed

- The theoretical speed a plane would fly with no drag
- Actual top speed will typically be ~ 70% to 90% of pitch speed depending on how much drag the airplane has and the prop. This is very hard to estimate precisely.

3) Pitch Speed

- Cool rule of thumb:

At 10,500 RPM

Pitch Speed = Pitch X 10

13x8 = 80 mph
14x7 = 70 mph (at 10,500 RPM)
14x6 = 60 mph

3) Pitch Speed

At 10,500 RPM

Pitch Speed = Pitch X 10

Four Star 40 prop 11x7 = 70 mph

Glow engines in the air run ~ 10,000 RPM
(Not RPM on the stand)
The recommended glow prop gives a good idea
what pitch speed is good for the model

3) Pitch Speed

- Adjust estimate based on expected RPM

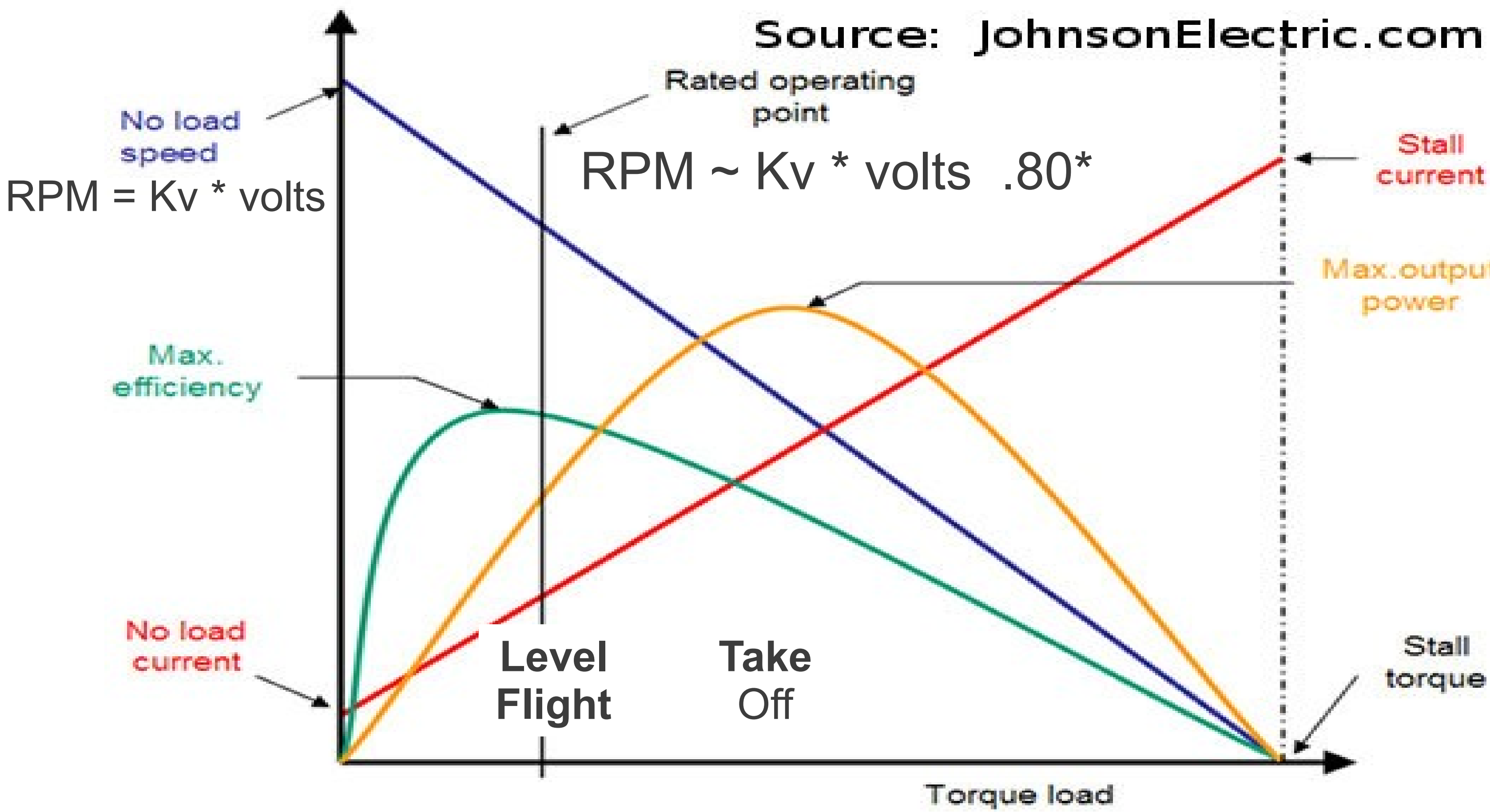
At 8,400 RPM

(80% of 10,500)

Increase Kv or voltage to raise RPM up to 10,500 if a prop similar to a glow prop is desired.

13x8 = 80 x .80 = 64 mph
14x7 = 70 x .80 = 56 mph
14x6 = 60 x .80 = 48 mph

3) Estimating Pitch Speed



Assumes the prop is recommended for that motor and voltage

3) Example

- To electrify a Four Star 40:
  - Eflite Power 32 (700 watts, 770 kV) 3 to 5 S

Power 32 / <u>**4S**</u> pack no load speed = 770*16 = 12,320 RPM

12,320 * .8 = 9850 RPM

9850/10500 * 10 * 7 = 66 mph

Using a 4S pack lets you use a 12x7 prop.
The same prop as recommended with a Saito 56 glow.

3) Glider Examples

- Radian Glider
  - 960 Kv * 12v * 0.80 = 9200 RPM (flying)
  - Pitch = 7.5
  - (9200 / 10,500) * 7.5 * 10 = **66 mph**

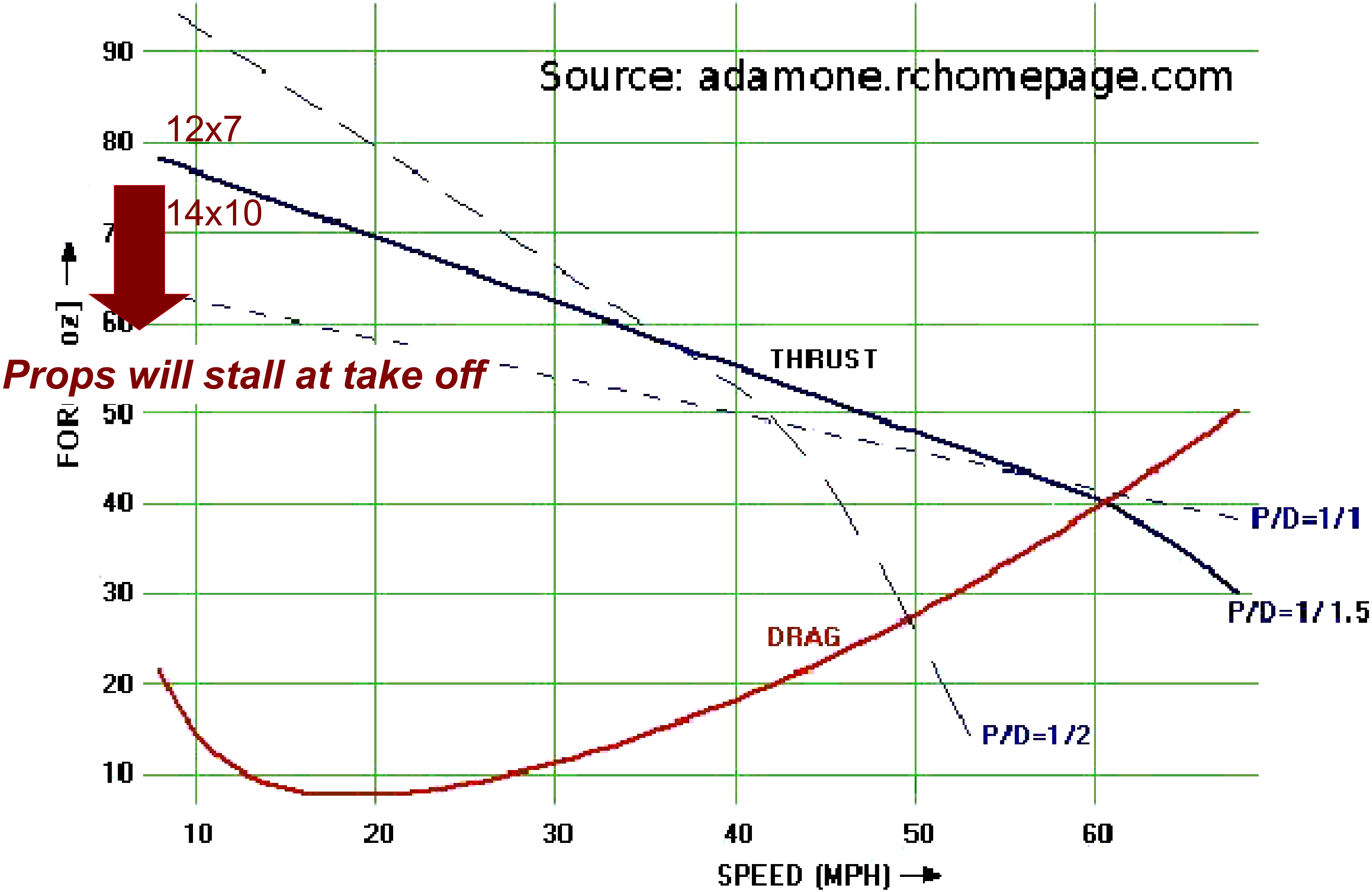
- Mystique Glider
  - 870 Kv * 12v * 0.80 = 8300 RPM (flying)
  - Pitch = 8.0
  - (8300 / 10,500) * 8.0 * 10 = **63 mph**

4) Prop Diameter

- Larger diameters grab more air, typically generate more thrust
- Larger diameters take more power
- Clearance can limit prop size
- Three blade props less efficient than a larger two blade prop, but sometimes used when clearance is an issue.

Electric props are thinner, more efficient than glow props

P/D = 1/1: "square prop" 5x5, 6x6, 7x7 – Stalled at take off
P/D = 1/1.5: 9x6, 12x8, 15x10 – Typical for Sport
P/D = 1 / 2: 12x6, 14x7, 16x8 – Better for 3D, consistent speeds



Confirm Current Draw

- Ecalc.ch or other simulator
  - Valuable for optimizing prop (especially diameter)
  - Estimating flight time
- Refer to manufacturers recommendations
  - For motor AND pack voltage
- **Power meter recommended for new systems**

Common Connectors

- JST
  - For small indoor fliers, < 5 amps

- EC3 (blue connectors)
  - 60 amp max current
  - Can be separated with snap ring pliers

- Deans Ultra Plug(red T connectors)
  - ~60 amp max current
- EC5 (max current 120 amps)

Summary

- Power (> 100 watts per lbs)
- Pack (~ 4 volts per cell)
  - My favorite packs 3S 2100, 4S 3300
- Pitch Speed (mph)
  - At 10,500 RPM = 10 * Pitch (inches)
- Prop D/P ratios
  - > 1.5 improve low speed handling
  - 2.0 or greater for 3D
- Confirm setups with watt meter
  - Props vary